Characterization of native and modified starches from lotus *(Nelumbo nucifera* G.) seeds and rhizomes

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Detailed synopsis for registration to Ph. D. program in Food Science & Technology

Proposed title of Ph.D. thesis: Characterization of native and modified starches from lotus *(Nelumbo nucifera* G.) seeds and rhizomes

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Introduction

Lotus (*Nelumbo nucifera* G.) commonly known as Indian lotus, chinese water lilly and sacred lotus belongs to the family of *Nelumbonaceae.* It has been cultivated in China, India, Thailand, South Korea, Japan and Australia (Bhat et al., 2008; Kim et al., 2012). Lotus is a perennial, large and rhizomatous aquatic herb with slender, elongated, branched, creeping stem consisting of nodal roots; leaves are membranous and peltate (60-90 cm and above). Almost all parts of the lotus plant, including its seeds, leaves, pods, and rhizomes are used. The rhizomes are 60-14 cm long, 0.5-2.5 cm in diameter, yellowish white to yellowish brown, smooth and with nodes and internodes (Mukherjee et al., 1998). Lotus plants develop several rhizomes in a single growing season with average length of 10-20 cm each. Large quantities of nutrients are produced and stored in these rhizomes (Masuda et al., 2006, 2007). Lotus seeds are mostly oval or spherical, with sizes varying according to varieties. They are generally 1.2-1.8 cm long, with diameter ranging from 0.8-1.4 cm and a weight of 1.1-1.4 g. After lotus seeds have been decorticated and peeled, they are edible and rich in nutrients, and can be dried for storage (Wang et al., 2010). The lotus rhizomes are rich in minerals and are consumed as health foods. Lotus seeds can be eaten either as cooked or raw form and are rich in health promoting compounds such as alkaloids, lipids, flavonols, carotenes, aporphine, nuciferine, phospholipids, flavonoids, xanthophylls, and minerals (Li et al., 2017)

Lotus seeds are rich in carbohydrates, proteins, amino acids, essential minerals and alkaloids. It is composed of 14% water, 4.05% ash, 2.05% fat, 16.2% crude protein, 8.13% sugar, 55.77 % starch. (Pan et al., 1993). It has approximately 50% starch with a high amount of amylose molecules (40%) (Zeng et al., 2009). Fresh rhizome is composed of 81.42% water, 0.07% fat, 0.52% sugars, 1.585% protein, 3.1% fibre, 0.26% calcium, 0.78% phosphorus, 3.63% potassium, 0.09% iron (Sheikh, 2014). It contains 31.2% starch, which shows no characteristic taste or odour (Fatima et al., 2018).

The particle surface of lotus seed starch is smooth, mostly oval, with a few having a round and irregular shape. The particle sizes of lotus seed starch range between 3 and 25 µm and degrees of polymerization 10,450. Lotus seed starch is C-type, which has a high

degree of crystallinity (Zeng et al., 2009; Zhang et al., 2014). Lotus rhizome starch granules are elongated and oval in shape (Man et al., 2012).The dimensions of lotus rhizome starch are 47.9 µm (length) and 25.9 µm (width) for large granules (Sukhija et al., 2015) and 10-50 µm in long axis and 10-35 µm in short axis for small granules. (Jane et al., 1994).

Lotus seeds have high starch content so they are easily processed into a variety of foods with appropriate excipients to meet the growing demand for modern nutrition and therapy. Starch has low solubility, low transparency, good thermal stability, fast retrogradation and swelling power; it is close to sweet potato starch with high freeze–thaw stability and low gel strength (Guo et al., 2013; Man et al., 2012). As other starches, lotus seed and rhizome starches are used as a thickening, stabilizing, gelling, filling, and water retention agent in food and non-food applications (Man et al., 2012).

Lotus seeds can be transformed into moon cake, lotus seed noodles, and breakfast foods such as paste, fermented milk, rice wine, ice cream and other products. Seeds have high antioxidant activity which may be processed into several food products including fried chips, pudding, biscuits, juice, beverages, and canned foods (Cai et al., 2008).The flour of lotus seed and rhizome is gluten free, and can be developed as a major ingredient for gluten-free food products to aid people with celiac disease (Zhang et al., 2015).

Lotus seed are used as food and pharmaceutical products in India, China, and Japan to treat tissue inflammation, cancer, diuretics, skin diseases insomnia, palpitations, fever, poor digestion, chronic diarrhea, enteritis, tissue inflammation, and as poison antidote (Mani et al., 2006). Fresh lotus seed wine with yeast fermentation has thirst quenching, spleen and antidiarrheal advantages after drinking (Wu et al., 2013). Recent studies have shown that the functions of lotus seed extracts are protecting the liver, scavenging free radicals and anti aging due to their rich flavonoids, polysaccharides, and alkaloids (Masuda et al., 2006; Masuda et al., 2007; Zhong et al., 2007). Lotus rhizome contains high levels of polysaccharides, is nutritious and could be used for the treatment of diarrhoea, dysentery and dyspepsia in children (Jane, 1993). The rhizome node is

traditionally used for the treatment of nasal bleeding, hematuria and functional bleeding of the uterus (Yang et al., 2007).

The study is proposed with the following objectives:

- Isolation of starch from seeds and rhizomes of lotus *(Nelumbo nucifera* G.).
- Modification of isolated starches from lotus seeds and rhizome.
- Characterization of starches from seeds and rhizome of lotus and comparison with other starches.
- Application of lotus seed and rhizome starches.

Review of literature

Lotus (*Nelumbo nucifera* Gaertn.), a member of the family *Nymphaeaceae,* is an aquatic herb vegetable. Lotus is a perennial aquatic plant. It belongs to the small family of *Nelumbonaceae*, comprising of only one genus Nelumbo with two species: *Nelumbo nucifera Gaertn.* and *Nelumbo lutea Pear.*, which are popularly named as Asian lotus and American lotus, respectively (Wang et al., 2005; Zhang et al., 2011; Li et al., 2014). These two species differ in their external morphologies, such as petal color and shape, leaf shape and plant size (Shen-Miller, 2002). Lotus seeds consist of 10.5% moisture, 10.6-15.9% protein, 1.93-2.8% crude fat, 70-72.17% carbohydrate, 2.7% crude fiber, 3.9-4.5% ash (Reid, 1977; Indrayan et al., 2005) and minerals 1% sodium, 28.5% potassium, 22.1% calcium, 9.2% magnesium, 0.05% copper, 0.08% zinc, 0.35% manganese and 0.19% iron. Lotus rhizome consists of 1.7% protein, 0.1% fat, 9.7% carbohydrate and 1.1% ash (Reid, 1977).

Lotus (*Nelumbo nucifera* G.) seeds are a popular food consumed in Asia due to their abundant contents of nutrients and bioactive substances (Zhang et al., 2015). Lotus seeds are used as spleen tonic and seed powder is used against cough. Plumule from the ripe seed is used for the treatment of many diseases, including nervous disorders, insomnia, high fevers with restlessness and hypertension. The seeds or their extracts have been reported to possess anti-fibrosis, anti-depressant, anti-inflammation, free radical scavenging, anti-obesity and antiviral activities (Kashiwada et al., 2005). Lotus rhizome contains abundant starch, proteins and vitamins, making it a popular edible vegetable (Zhang et al., 2011; Yang et al., 2015). Enlargement of lotus rhizome could largely determine its economic value. In addition, the enlarged rhizome could also help the lotus to survive in winter during its bud dormancy, and provide substrates and energy for its asexual propagation. To increase its yield in agricultural production, genetic and transcriptomic studies are used for the enlargement of the rhizome. Lotus rhizome and its extracts have shown diuretic, psychopharmacological, anti-diabetic, anti-obesity, hypoglycemic, antipyretic and antioxidant activities (Mukherjee et al., 1996).

Ito et al. (1996) observed that lotus seed starch (27.7%) has higher amylose content than rhizome starch (21.7%). Lotus seed starch had total starch content 90.12%, moisture content 8.47%, protein content 0.98% with an amylose : amylopectin ratio of 45:55 (Zhang et al., 2014). Lotus rhizome starch had higher amylose content 20.6% than green banana 19.2%, elephant foot yam (*Amorphophallus paeoniifolius*) 14%, taro (*Colocasia esculenta)* 4.3%, and ginger 12.5% starches (Sukhija Singh et al., 2015). (Suzuki et al., 1992) observed amylose content of 15.9% in lotus rhizome starch as calculated from iodine affinity. (Man et al., 2012) reported the amylose content of 23.9% and 38.9% for rhizome and seed starches as measured by iodine-binding spectrophotometry-based method.

Lotus seed starch was subjected to high-pressure up to 600 MPa. (Guo et al., 2013; Guo, et al., 2015a; Guo et al., 2015b) reported that high pressure decreased the gelatinization temperatures and ΔH of DSC analysis, and BD and SB of pasting profile. PV of pasting was increased by high pressure. High pressure decreased the stress yield, and increased the consistency coefficient of flow curves, and reduced the starch retrogradation. High pressure treatments decreased the swelling power and solubility at 85 and 95◦C, while increasing them at 55-75◦C. Dynamic rheological analysis showed that pressure of 100-500 MPa increased G' and G", while 600 MPa decreased them. High pressure decreased the recovery capacity of starch paste upon shearing.(Zhang, 2016 ; Zobel, 1988) reported that at high pressure homoginization treatment of >150 MPa x-ray diffraction pattern of lotus seeds starch transformed from a C-type into B-type pattern due to this, internal crystalline structure of lotus seed starch was significantly destroyed.

Bhat et al. (2010) evaluated that 10-15 kGy dose of electron beam and γ-ray irradiation was effective sterilization dose with least effects on lotus seed nutrition and functional properties. The protein contents are increased after γ-ray irradiation, but decreased after electron beam irradiation. Starch content increase as well as total phenol decreases upon exposure to γ and electron beam irradiations Lotus rhizome starch when treated with γ-irradiation at 5, 10 and 20 kGy increased the carboxyl content, amylose leaching, water absorption capacity, and gel transmittance of starch, while decreasing the degree of

crystallinity, swelling power, apparent amylose content, syneresis, and pasting viscosity. Some granules were damaged, and the polymorph type remained the same. The impact appeared to be dose-dependent (Gani et al., 2013). Fresh lotus seeds are nutritious but also vulnerable to microbial contamination, especially fungal infections. Therefore, sun drying combining with charcoal method is used to preserve the lotus seeds but it is time-consuming, results in large loss of nutrients and poor quality, and is difficult to control. Therefore, microwave drying and vacuum freeze-drying technology have become hotspot in lotus seed drying for storage in recent years. Freeze-dried lotus seeds not only have longer shelf life, but also maintain original nutrients, and no differences is found in flavor compared to fresh lotus seeds after rehydration (He et al., 2006).

Lotus rhizome starch has been subjected to acetylation and hydroxypropylation (Gunaratne et al., 2018) reported that there is decrease in pasting viscosity, and increase in light transmittance, swelling and solubility, and freeze-thawing stability and when lotus rhizome and seed starches have been subjected to acid hydrolysis at various conditions (Cai et al., 2014) reported that acid treatment reduced the swelling power, solubility, water binding capacity, and pasting viscosity of lotus rhizome starch, while increasing the paste syneresis (Kaur et al., 2011). Acid treatment decreased apparent amylose content and gelatinization ΔH of lotus rhizome starch, and increased Tp and Tc of gelatinization. The seed starch had a faster hydrolysis rate than rhizome starch. (Cai et al., 2014). The structural changes of starch during acid hydrolysis were monitored by various techniques (Cai et al., 2014).

Significance of the study

India demands around 27,500 tons of modified starch per annum, with a growth rate of 8–9% per annum. Corn is the major starch source for industrial application and is also a staple food. However, non-conventional starch sources like lotus seeds and rhizomes are not utilized in industries as they are not well explored to date for their inherent properties. There has increasing interest in starch from novel or non-conventional botanical sources because these starches may have different physicochemical and functional properties than those of conventional starches and these starches can meet the huge demand for food industries without affecting the supply of staple crops required for table consumption. Native starch has its limitation in food application with some of disadvantages including loss of viscosity at low pH value, high processing temperature or mechanical treatments, long texture and retrogradation. So, the properties of lotus seeds and rhizome starches can be improved by modification treatments and may be used to develop new processes and consequently new products. Hence, the present research has shown to study the effect of modification on the physicochemical, thermal, pasting, structural, and morphological characteristics of lotus seeds and rhizome starches.

Materials and Methods

Materials Lotus seeds and rhizomes will be procured from local market Sirsa.

Methods

Starch isolation Starch will be isolated from lotus seeds and rhizome by using suitable method / methods.

Swelling power and solubility Swelling and solubility of starches will be determined by using suitable method/methods.

Amylose content Amylose content of starches will be determined by using suitable method/methods.

Water absorption capacity Water absorption capacity of starches will be determined by using suitable method/methods.

Transmittance Light transmittance of starch pastes will be determined by using suitable method/methods.

Pasting and Rheological properties Pasting and rheological properties will determined by rheometer.

Structural, Morphological and Thermal properties Structural, Morphological and Thermal properties will be determined by using differential scanning calorimeter and scanning electron microscope, respectively.

Modification of starch Starch will be modified by using suitable method/methods.

Statistical analysis Data obtained through experimentation will be statistically analyzed using suitable software.

References

Bhat R., Sridhar K.R. (2008). Nutritional quality evaluation of electron beam-irradiated lotus (*Nelumbo nucifera* G.) seeds. Food Chemistry.107, 174-184.

Bhat R., Sridhar K.R., Karim A.A. (2010).Microbial quality evaluation and effective decontamination of nutraceutically valued lotus seeds by electron beams and gamma irradiation. Radiation Physics Chemistry.79, 976-981.

Cai L., Blazek J., Salman H., Tang M.C. (2008).Form and functionality of starch. Food Hydrocolloids. 23, 1527-1534.

Fatima T., Iftikhar F., Hussain S.Z. (2018). Ethno-medicinal and pharmacological activities of lotus rhizome. Journal Pharmcological Innovations.7(4), 238-241.

Gani A., Masoodi F.A., Wani S.M. (2013). Characterization of lotus stem (*Nelumbo nucifera* G.) starches purified from three lakes of India. Journal of Aquatic Food Product Technology. 22, 605-618.

Gunaratne A., Corke H.(2007). Functional properties of hydroxypropylated, cross-linked, and hydroxypropylated cross-linked tuber and root starches. Cereal Chemistry.84, 30-37.

Guo Z.B., Liu W.T., Zeng S.X., Zheng B.D. (2013). Effect of ultra high pressure processing on the particle characteristics of lotus-seed starch. Chinese Journal of Structural Chemistry. 32, 525-532.

Guo Z., Zeng S., Lu X., Zhou M., Zheng M., Zheng B. (2015a). Structural and physicochemical properties of lotus seed starch treated with ultra-high pressure. Food Chemistry. 186, 223-230.

Guo Z., Zeng S., Zhang Y., Lu X., Tian Y., Zheng B. (2015b). The effects of ultrahigh pressure on the structural, rheological and retrogradation properties of lotus seed starch. Food Hydrocolloids.44, 285-291.

Indrayan A.K., Sharma S., Durgapal D., Kumar N., Kumar M. (2005). Determination of nutritive value and analysis of mineral elements for some medicinally valued plants from Uttaranchal. Current Science. 89,1252-1255.

Ito T., Murase M., Yamada T., Namiki K. (1996). Properties of lotus-seed starch. Journal of Applied Glycoscience. 43, 7-13.

Jane J.L. (1993). Mechanism of starch gelatinization in neutral salt-solutions.Starch-Starke. 45,161-166.

Kaur M., Oberoi D.P.S., Sogi D.S., Gill B.S. (2011). Physicochemical, morphological and pasting properties of acid treated starches from different botanical sources. Journal of Food Science & Technology.48, 460-465.

Kashiwada Y., Aoshima A., Ikeshiro Y., Chen Y.P., Furukawa H., Itoigawa M., Fujioka T., Mihashi K., Cosentino L.M., Morris-Natschke S.L., Lee K.H.(2005).Anti-HIV benzyl isoquinoline alkaloids and flavonoids from the leaves of (*Nelumbo nucifera* G.*)*, and structure activity correlations with related alkaloids. Bioorganization Medical Chemistry. 13, 443-448.

Kim M., Shin H. (2012). Antioxidative effect of lotus seed and seedpod extracts. Food Science Biotechnological. 21, 1761-1766.

Li S., Li X., Lamikanra O., Luo Q., Liu Z., Yang J.(2017).Effect of cooking on physicochemical properties and volatile compounds in lotus root (*Nelumbo nucifera* G*)*. Food chemistry. 216, 316-323.

Li Y., Smith T., Svetlana P., Yang J., Jin, J.H., Li C.S.(2014).Paleobiogeography of the lotus plant (*Nelumbonaceae: Nelumbo*) and its bearing on the paleoclimatic changes. Palaeogeographical Palaeoclimatological Palaeoecological. 399, 284-293.

Man J., Cai J., Cai C., Xu B., Huai H., Wei C. (2012) Comparison of physicochemical properties of starches from seed and rhizome of lotus. Carbohydratr Polymorphism 88,676-683.

Mani S., Wu X., Lin S., Zeng H., Lu X., Zhang Y., Zheng B. (2006).Structural characteristics and physicochemical properties of lotus seed resistant starch prepared by different methods. Food Chemistry.186: 213-222.

Masuda J.I., Ozaki Y., Okubo H. (2007*).* Rhizome transition to storage organ is under phytochrome control in lotus (*Nelumbo nucifera* G). Plantation. 226, 909-915.

Masuda J.I., Urakawa T., Ozaki Y., Okubo H. (2006). Short photoperiod induces dormancy in lotus (*Nelumbo nucifera* G). Animal Botanical. 97, 39-45.

Mukherjee P.K., Balasubramanian R., Saha K., Saha B.P., Pal M. (1996). A review of (*Nelumbo nucifera* G). Ancient Science Life. 15, 268-276.

Pan Y., Cai B., Yang G., Cao L., Shen A. (1993). Screening of active components of plumula Nelumbinis nucifera for lowering blood sugar. Journal Nanjing TCM University. 21, 243-244.

Reid B.E. (1977). Famine Foods of the Chiu-Huang Pen-ts'ao. Southern Materials Centre, Taipei.67, 67-74.

Sheikh S.A. (2014). Ethno-medicinal uses and pharmacological activities of lotus *(Nelumbo nucifera G).* Journal Medical Plants Studies . 88, 42-48.

Shen-Miller J. (2002).Sacred lotus, the long-living fruits of China Antique. Seed Science Resources.12, 131-143

Sukhija S., Singh S., Riar C.S. (2015). Isolation of starches from different tubers and study of their physicochemical, thermal, rheological and morphological characteristics. Starch-Starke. 67, 1-9.

Wang Q., Zhang X. (2005).Colored Illustration of Lotus Cultivars in China; China Forestry Publishing House: Beijing, China.

Wang J., Zhang G., (2010). The yield and chemical composition of lotus seed on different culture conditions. Hubei Journal TCM. 32, 75-76.

Wu F., Xiao G. (2013). Nutritional properties of lotus seeds and its application in functional foods. Subtropical Agriculture Resources. 8,274-278.

Yang D.M., Wang Q.S., Ke L.Q., Jiang J.M., Ying T.J. (2007). Antioxidant activities of various etracts of lotus *(Nelumbo nuficera* G.) rhizome. Asia Pacific Journal Clinical Nutrition. 16,158-163.

Yang M., Zhu L., Pan C., Xu L., Liu Y., Ke W., Yang P. (2015). Transcriptomic Analysis of the Regulation of Rhizome Formation in Temperate and Tropical Lotus (*Nelumbo nucifera* G). Science Reproduction. 5, 13-59.

Zeng S., Zheng B., Lin Y., Zhuo X. (2009). Granular characteristics of lotus-seed starch. Journal Chin Cereals Oils Association. 8: 62–64

Zhang X., Chen L., Wang Q. (2011). New Lotus Flower Cultivars in China; China Forestry Publishing House: Beijing, China.

Zhang Y., Lu X., Zeng S., Huang X., Guo Z., Zheng Y., Tian Y., Zheng B.(2015). Nutritional composition, physiological functions and processing of lotus (*Nelumbo nucifera G.)* seeds: A review. Phytochemical Review. 14, 321-334.

Zhong G., Chen Z.D., We Y.M. (2007). Physicochemical properties of lotus (*Nelumbo nucifera* G.) and kudzu (*Pueraria hirsute* M.) starches. International Journal Food Science Technology. 42, 1449-1455.

Zhang K., Qiyu L.U. (2016). Relationship between the type-A and type-B starch and the gelatinization characteristics of wheat flour. Journal Henan University Technology. 37, 18-22.

Zhang Y., Zeng H., Wang Y., Zeng S., Zheng B. (2014) .Structural characteristics and crystalline properties of lotus seed resistant starch and its prebiotic effects. ood Chemisty.5(19), 311-318.

Zhang Y., Lu X., Zeng S., Huang X., Guo Z., Zheng Y., Zheng B. (2015). Nutritional composition, physiological functions and processing of lotus(*Nelumbo nucifera* G)seeds: A review. Phytochemistry Reviews. 4(3), 321-334.

He F., Lu X., Zeng S. (2007). Structures, properties and applications of lotus starches. Food Hydrocolloids. 63,32-348.

Zobel, H.F. (1988).Molecules to Granules: A Comprehensive Starch Review. Starch-Starke. 40,44-50.